

THE DEVELOPMENT OF AN ENGINEERING COMPUTER GRAPHICS LABORATORY

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INTRODUCTION

Computer graphics has rapidly gained recognition in industry and academia as a powerful tool for engineering design and analysis. This apparent popularity has generated increasing interest in new display hardware and an even greater demand for systems and applications software. In this atmosphere, the Computer Aided Design and Graphics Laboratory in the School of Mechanical Engineering at Purdue University evolved as an environment for research and education in interactive computer graphics.

This presentation describes the development of the laboratory in terms of the hardware and software system and several of the ongoing application-oriented projects, educational graphics programs, and graduate research projects. In keeping with the spirit of graphical communication, a motion picture film was prepared to graphically describe the laboratory and the projects. The remainder of this paper summarizes the material in this film, and the narration at the presentation.

THE SYSTEM

The equipment configuration used by the majority of laboratory projects is depicted in figure 1. Current development efforts in interactive graphics employ the Digital Equipment Corporation PDP 11/40 minicomputer as the primary computation processor and the Imlac PDS-1 as an intelligent display processor. Data paths from the PDP to the Tektronix 4014 storage tube terminal, the Calcomp 502 76 cm (30 in.) flatbed plotter (via a microcomputer buffer processor), and the Purdue remote access terminal system provide a broad base for applications programming.

The software system consists of a FORTRAN IV subroutine package in the PDP 11/40 that interacts with a graphics operating system in the Imlac. Subroutine calls from the user's program executing in the PDP are transferred to the Imlac executive, where the corresponding routine is processed. The package comprises a comprehensive set of graphics routines for dynamic, structured two-dimensional display manipulation, and numerous routines to handle a variety of input devices at the Imlac.

The design objective during the continuing development of the system is to provide the application programmer (typically an engineer versed in FORTRAN) an interface between his problem and graphical interaction in as efficient and "learnable" manner as possible. The success of the interface, and consequently, the success of the system is measured by the applications it supports.

APPLICATIONS

The following paragraphs briefly describe a representative sampling of engineering application projects conducted in the laboratory. The individual projects vary from small educational programs demonstrating solutions to engineering problems to graduate research in three-dimensional graphical systems. Figures 2 through 10 are single frame "snapshot" plots from each project, generated on the Calcomp 502 directly from the Imlac. Figure 1 was created interactively using a general purpose documentation program and plotted directly from the PDP 11/40.

The first project involves three dimensional data generation and manipulation. A three dimensional cursor controlled by the user manipulates objects consisting of parametric curves and surfaces. The generated data can be passed to analysis programs, or used as input to this program during subsequent design sessions. Figure 3 shows a pictorial view of a boat hull composed of six bi-cubic surface patches. The bottom view depicts the boundary curves shown in the top view with additional trace curves for greater surface detail.

The general transformation capabilities of the preceding system are demonstrated with the rotation of a three-dimensional linkage (figure 4). Real time rotation aids kinematics students in the visualization of complex three-dimensional motion.

Undergraduate students in Mechanical Engineering design courses "see" solutions to their design projects using the demonstration programs shown in figures 5 and 6. On-line modification of system parameters gives immediate analysis feedback to the student.

The results of a computer simulation of the dynamic motion of a reed valve compressor are displayed in figure 7. The program operates on the data produced by a large analysis program which is a research project conducted in the School of Mechanical Engineering by Dr. Werner Soedel and Dennis Strader. The display is interactively controlled by the user; thus graphical evaluation of the complex dynamical simulation is facilitated.

A program to display the vibration of a two degree of freedom spring-mass-damper system is shown in figure 8. The instructions beneath the graph describe the options available to the user. The program was a student project for the advanced computer graphics course.

Free transverse vibration of a cylinder fixed at both ends is displayed in figure 9. The user can start and stop the vibration, alter the modes of vibration, vary the linework grid size, and control the viewing direction interactively at the Imlac. For relatively coarse grids such as one shown in the figure,

the response rate is sufficient to view the motion as it is calculated. To compensate for the displeasingly slow response rate with large numbers of grid lines, a motion picture camera was mounted to the Imlac and cycled frame-by-frame by the PDP program. The film gives a smooth, realistic display of complex cylinder motion that in the past was virtually indescribable to mechanical vibration students.

The ability to produce high quality, realistic graphical output using the hidden line removal and shading programs is a valuable asset to the computer graphics laboratory. Figure 10 shows a view through the windows into the new laboratory site and a bow view of a sailboat hull. The block letter titles in figure 2 are actually a collection of three-dimensional planes that were automatically generated and passed to the hidden line program by a special lettering program. The data for these pictures can also be passed to the shading program that generates a continuously shaded image consisting of raster point data. This data is plotted on the Imlac or Tektronix screens to give a realistic representation of the original three-dimensional picture.

CONCLUDING REMARKS

The authors extend their appreciation to Michael Bailey, John Brewer, Donald Riley, and Dr. Phillip White for the use of their projects and time in preparing the film.

The following list of Purdue University theses document the development of the laboratory through a history of graduate research efforts:

1. Anderson, David C.
"The Development of a General Purpose Interactive Graphics System", Ph.D., December 1974.
2. Applegate, Sheldon L.
"An Interactive Computer Graphics Approach to Four Bar Linkage Design", M.S.M.E., August 1975.
3. Belleville, Robert L.
"The Design and Development of an Interactive Computer Graphics System", M.S., June 1969.

"Man-Machine Communication: An Examination of the Machines", Ph.D., August 1974.
4. Gunn, Moira A.
"On the Development of Computer Graphic Design Tools for the Enhancement of Creativity", Ph.D., May 1974.
5. Palmer, John L., Lieutenant Colonel
"Design Education Stimulated by Interactive Graphics Notation (DESIGN)", Ph.D., December 1973.

6. Putnam, Richard E.
"A Strategy in Computer Graphical Input: An Aid to Visual Design", Ph.D.,
August 1973.
7. Reed, Walter S.
"Human Form and Motion Simulation", M.S., January 1970.
8. Stowell, Garrett W.
"A Two Dimensional Hardware Scheme for Rotation, Translation, and
Scaling of Computer Graphic Images", M.S.M.E., August 1971.

"Three Dimensional Display Processing Implementation of a Real-Time
System, Ph.D., December 1974.
9. White, Phillip R.
"The Interactive Creation and Display of Three Dimensional Graphics",
Ph.D., May 1975.

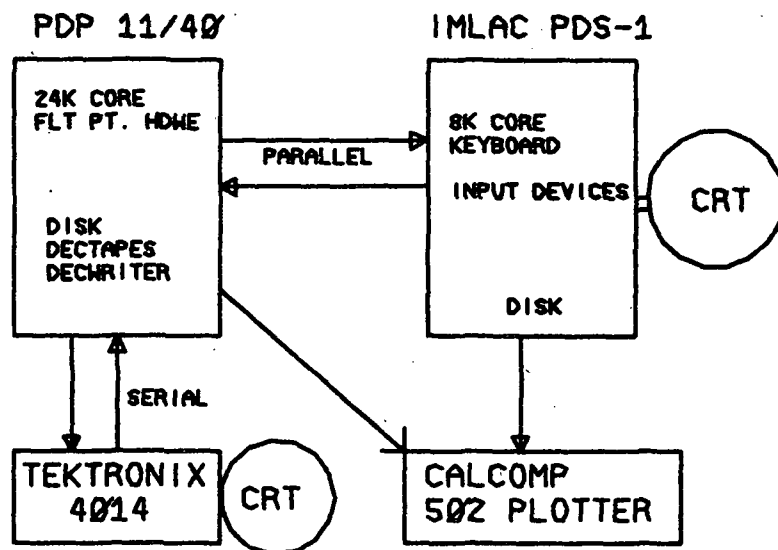


Figure 1. - The equipment configuration.

PURDUE UNIVERSITY

GRAPHICS

Figure 2. - Three-dimensional block letters with hidden lines removed.

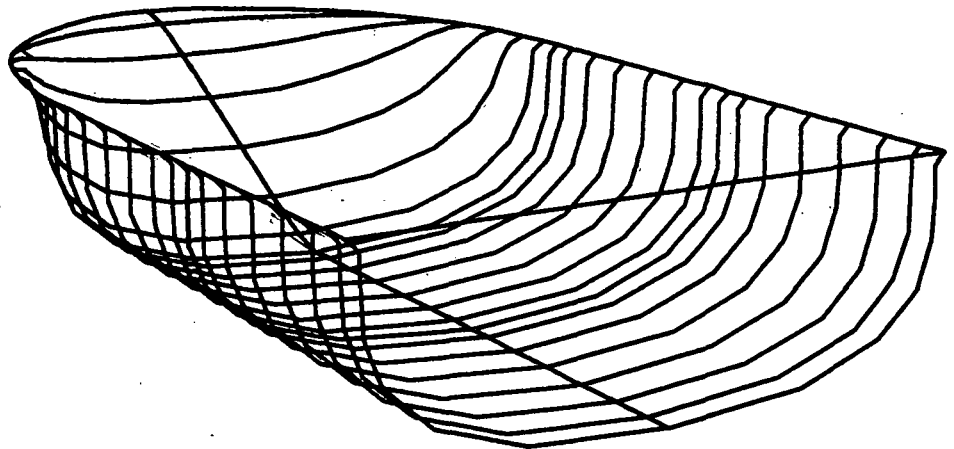
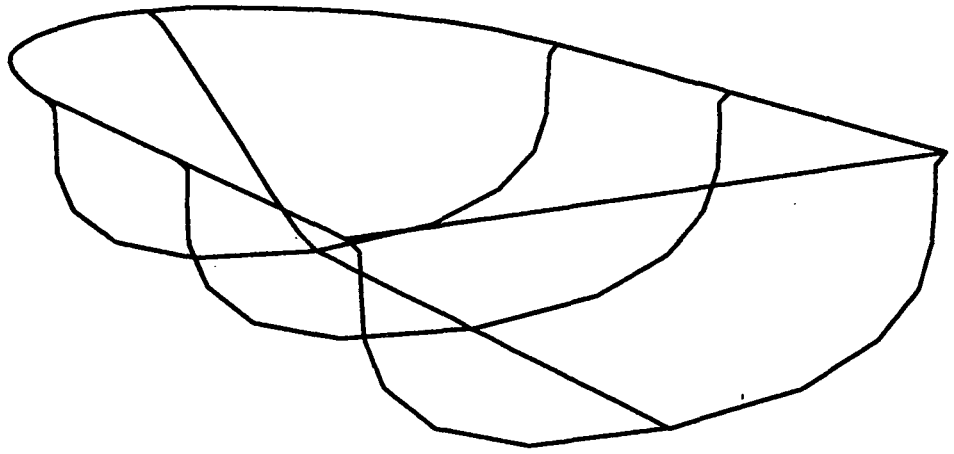


Figure 3. - Two views of a boat hull interactively formed from six surface patches.

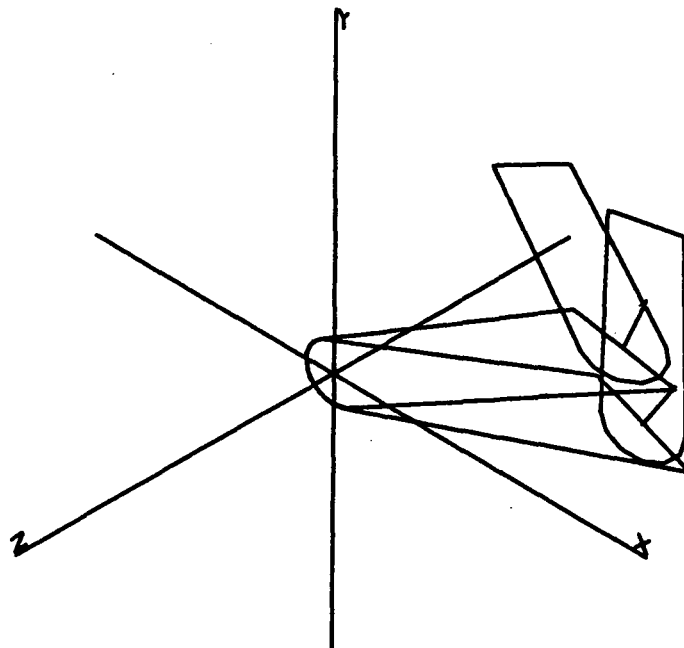


Figure 4. - Two positions of rotation of a three-dimensional linkage.

R/SHIFT R = DECREASE/INCREASE CRANK LENGTH
L/SHIFT L = DECREASE/INCREASE CONN. ROD LENGTH
H/SHIFT H = DECREASE/INCREASE OFFSET HEIGHT
M = MOVE
F = FASTER
S = SLOWER
(HOME) = STOP

R/S = 0.488
H/S = 0.244
L/S = 1.220
TIME RATIO = 1.133
CAMMAX = 53.13

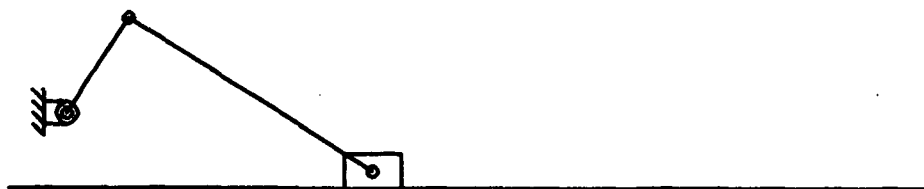


Figure 5. - The interactive motion analysis of an offset slider crank linkage.

INVERTED SLIDER CRANK STRAIGHT LINE GENERATOR

C = CONTINUOUS MOTION
I = INCREMENT WITH ERROR DISPLAY
F = FASTER
S = SLOWER
O = OSCILLATE ON/OFF
E = SET ERROR LIMIT
B = CHANGE PROPORTIONS
(HOME) = STOP

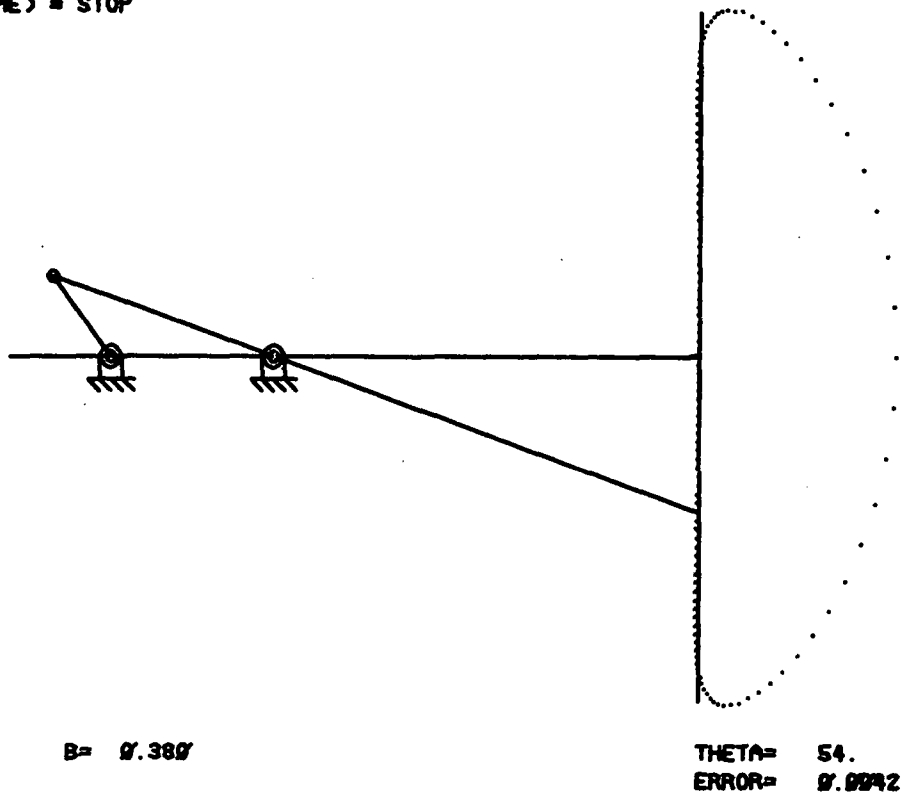


Figure 6. - The interactive dynamic analysis of an inverted slider crank linkage.

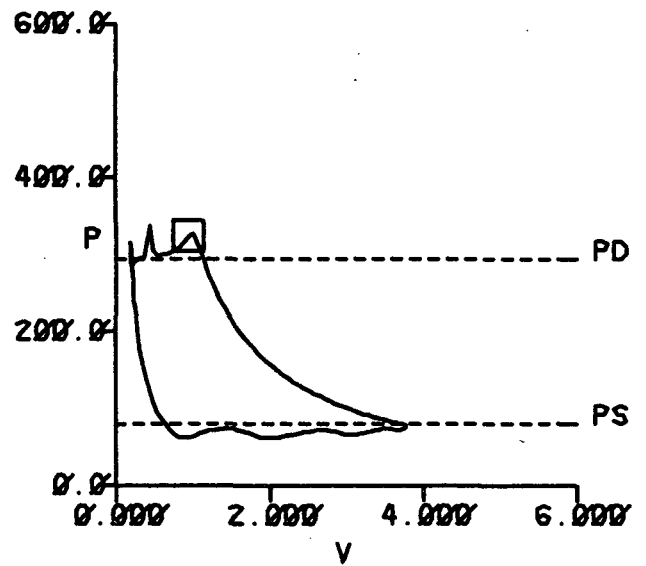
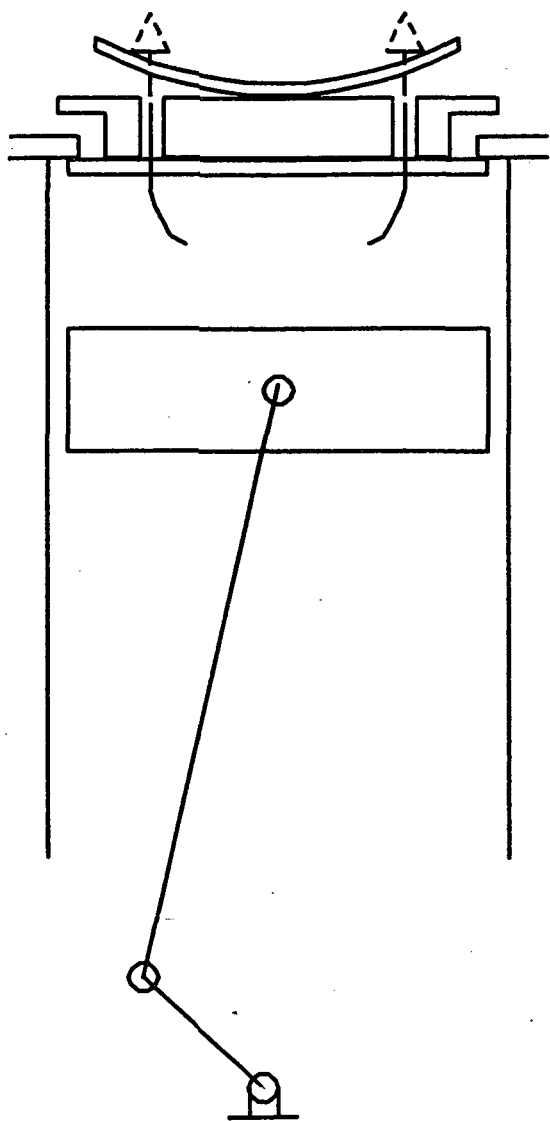
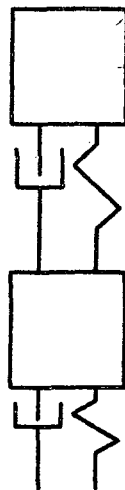
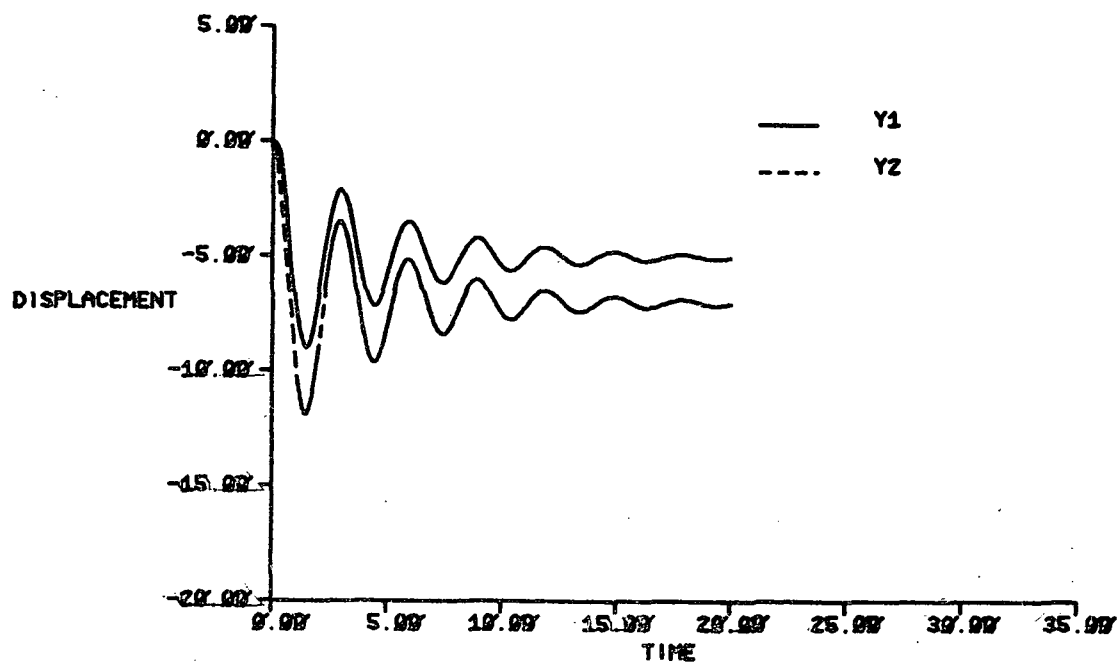


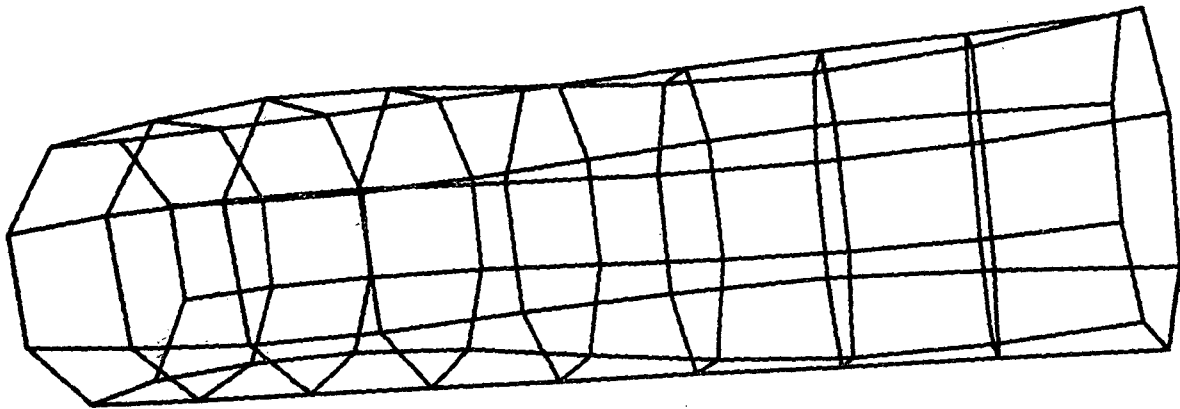
Figure 7. - The graphical display of a computer simulation of a reed valve compressor.



- 1= SEE MOVEMENT
- 2= MODIFY PARAMETERS
- 4= SAVE GRAPH
- 8= GET STORED GRAPH
- 31= EXIT

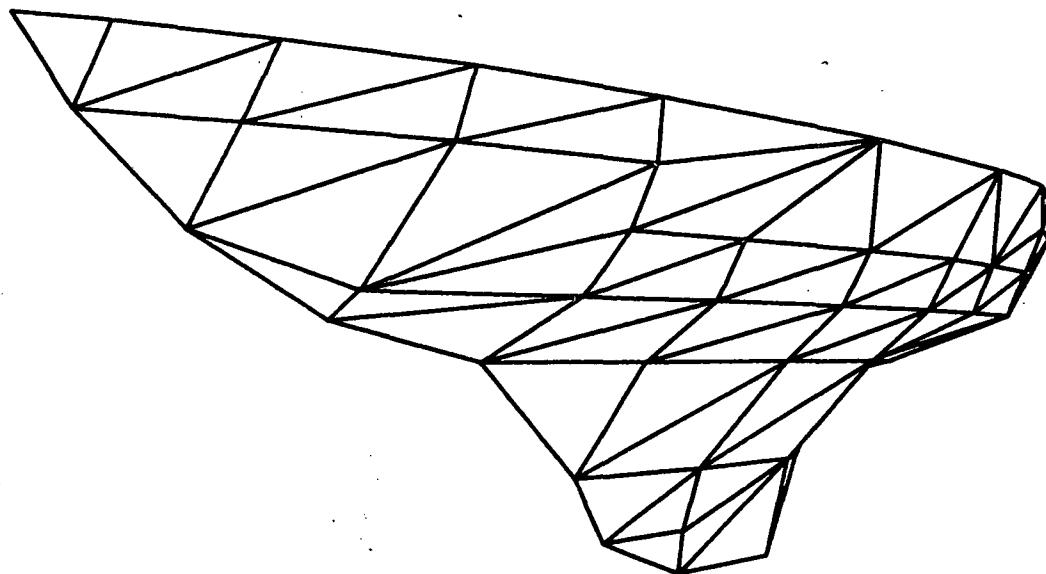
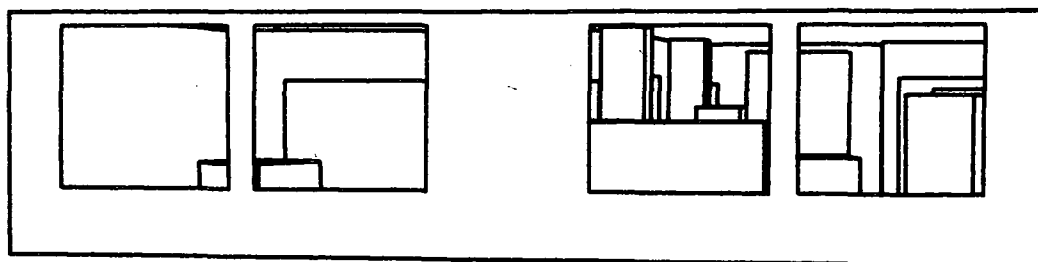
Figure 8. - Interactive display of the vibrations of a spring-mass-damper system.

KEYSET 3 TO DISPLAY INSTRUCTIONS



M= 2 N= 1 DT= 2.526 MICRO SECONDS

Figure 9. - Interactive three-dimensional display of the free transverse vibration of a cylinder.



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Figure 10. - Three-dimensional scenes with hidden lines removed.